Condition Monitoring and Predictive Maintenance

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Asset Management and Network Simulation
Condition Monitoring & Predictive Maintenance for Infrastructure

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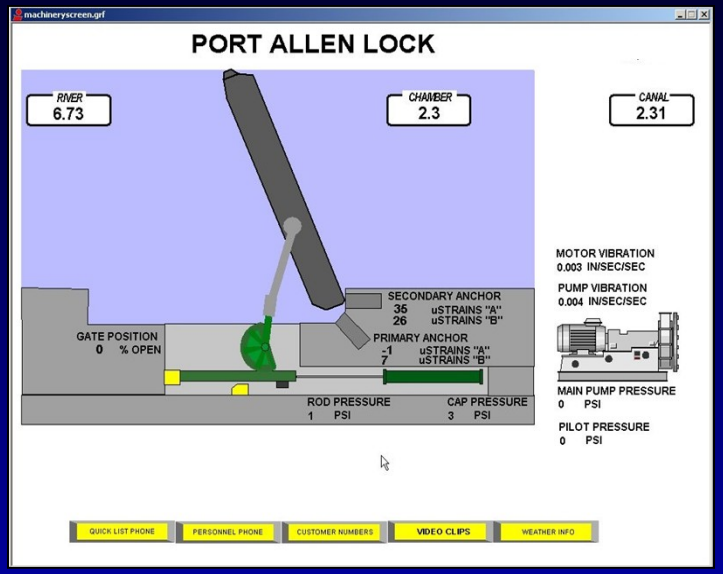
- **Problem:**
  - Unscheduled maintenance can be disruptive and costly
  - Lock and dam gates are subject to failure due to excessive loads and wear of components
- **Products:**
  - Condition monitoring baseline data for:
    - ⇒ Structural components_
    - ⇒ Lock operating machinery
  - Guidelines for Predictive Maintenance
- **Benefits:**
  - Provides real-time indication of overall electrical, mechanical and structural condition
  - Reduces the likelihood of failure of fracture critical components
  - Reduces maintenance cost and personnel requirements
  - Improves safety and reliability of lock gate, dam gate and pumping station operations



Benefits of Condition Monitoring

- Reduces
  - Maintenance cost and personnel requirements
  - Cost of dewatering and associated delays to navigation traffic
  - Need and frequency of scheduled inspection
- Provides indication of electrical/mechanical conditions
- Indicates corrective actions
- Circumvents premature failure of equipment

Condition Monitoring

- Condition Monitoring was initiated at Port Allen Lock (New Orleans District)
  - partnering with ERDC-CERL and St. Louis District
  - provided real-time data on the condition of lock [illegible] internet

- Port Allen Lock is on the Gulf Intracoastal Waterway (GIWW) between Morgan City, TX, and Port Allen, LA,

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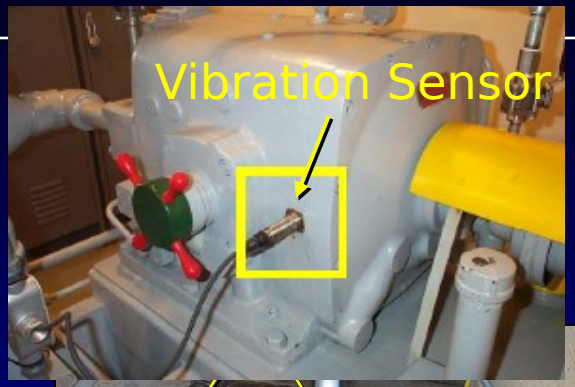
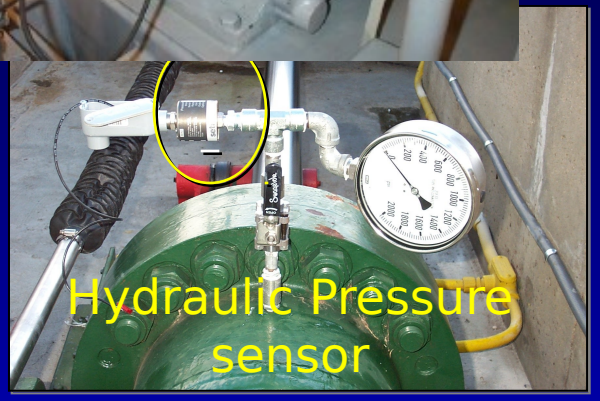
Port Allen Lock (New Orleans District)

- Establish Condition monitoring baseline data for
  - Lock operating machinery
    - Pump vibration, hydraulic oil pressure
  - Structural components
    - miter gate anchorage loading/strain

- Data acquired will be correlated with gate control machinery movement
  - interfaced to condition monitoring system



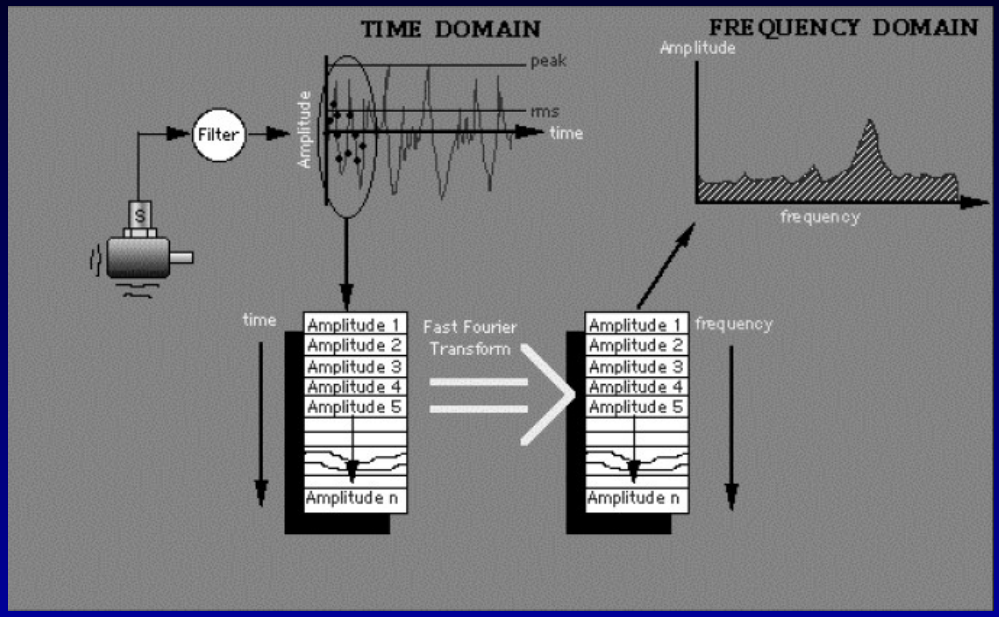


Hydraulic Pressure

- The operating pressure of hydraulic-operated machinery is directly related to the load under which that machinery is subjected.
  - simple and precise way to determine if operating conditions have changed.
- Interferences in the operation of a miter gate, for example, will cause the system operating pressure to be higher.
  - due to impending structural failure, impending mechanical failure, changing conditions such as siltation, or failure of electrical equipment.

Vibration Monitoring

- Analyze the frequency data derived from the transducer.
- The output of the transducer is passed through a filter to reject frequencies that are considered noise
- Use Fast Fourier Transform (FFT) will convert the signal to a frequency-based domain.



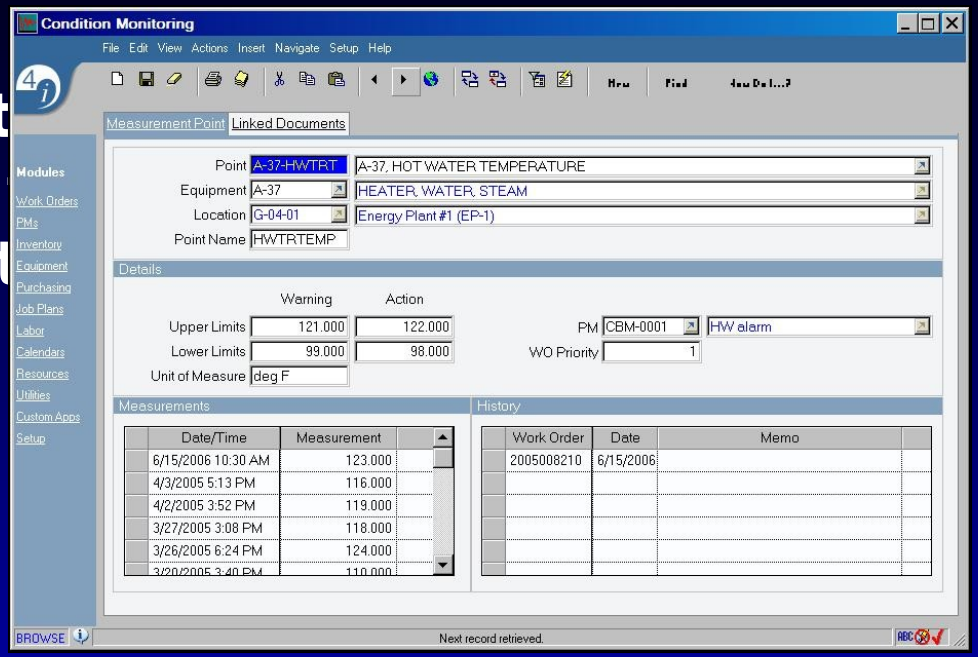
- Vibration spectrum allows indication of vibration caused by coupling inaccuracies, gear mesh, bearing faults, and many other sources.

FEM
(Facilities & Equipment Maintenance)

- Customized Maximo 4.1.1
- DoD sponsored program
- Tailored to meet USACE business needs
- Tool for asset management initiative
- Integrated with:
  - CEFMS
  - REMIS
  - APPMS
- VIMS functionality incorporated into system

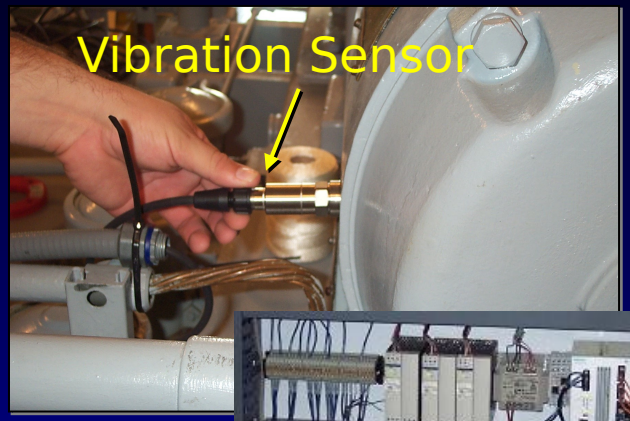
Condition Monitoring Application

- Used to tie equipment and asset measurement and maintenance plans warning and action limit values
- Warning limits only informational
- Once action limit is exceeded, generate pre-defined PM and Job Plan into Work Order

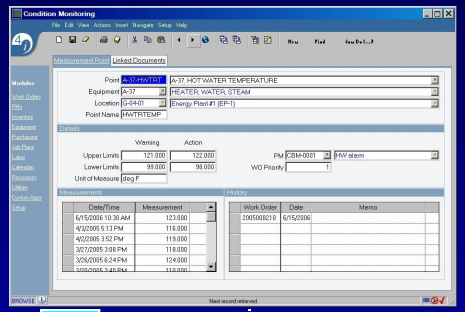


Displays history of measurements and CM generated work

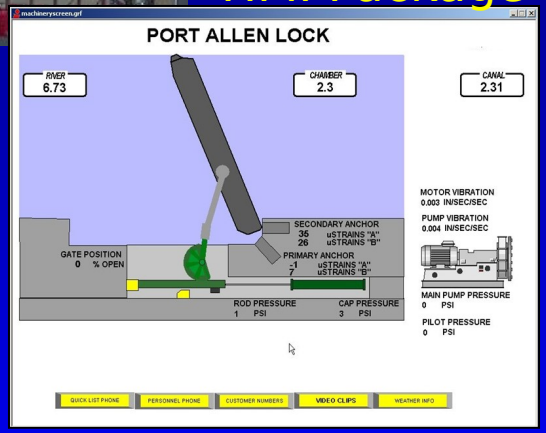
Condition Monitoring System



FEM



HMI Package

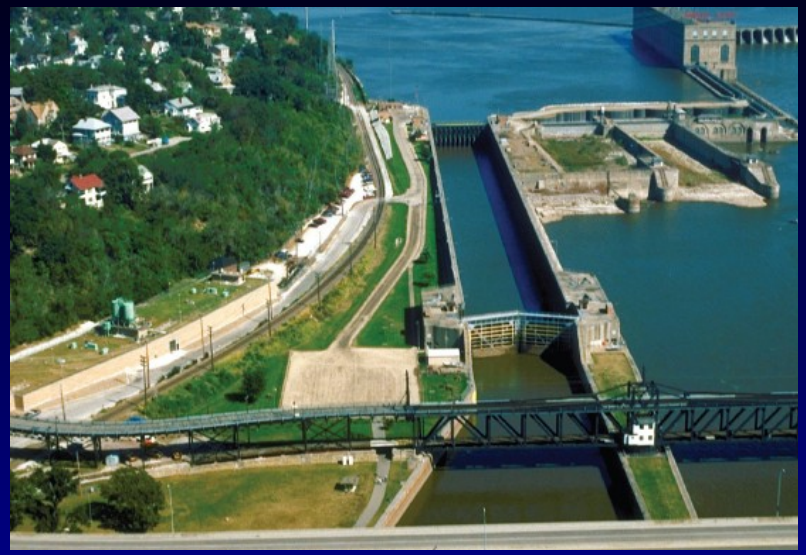


Work Orders

FY07 Research

- Collect data at Lock 19, Keokuk, Iowa (Rock Island Dist) on site for 6 months to establish baseline data for hydraulic pumps, motors, and miter gate structural components

- Sensors:
  - hydraulic cylinder position
  - Pressure, pool, tail, & lock water levels
  - Hydraulic oil flow rate
  - Temperature (oil & ambient)
  - Magnetic proximity switches

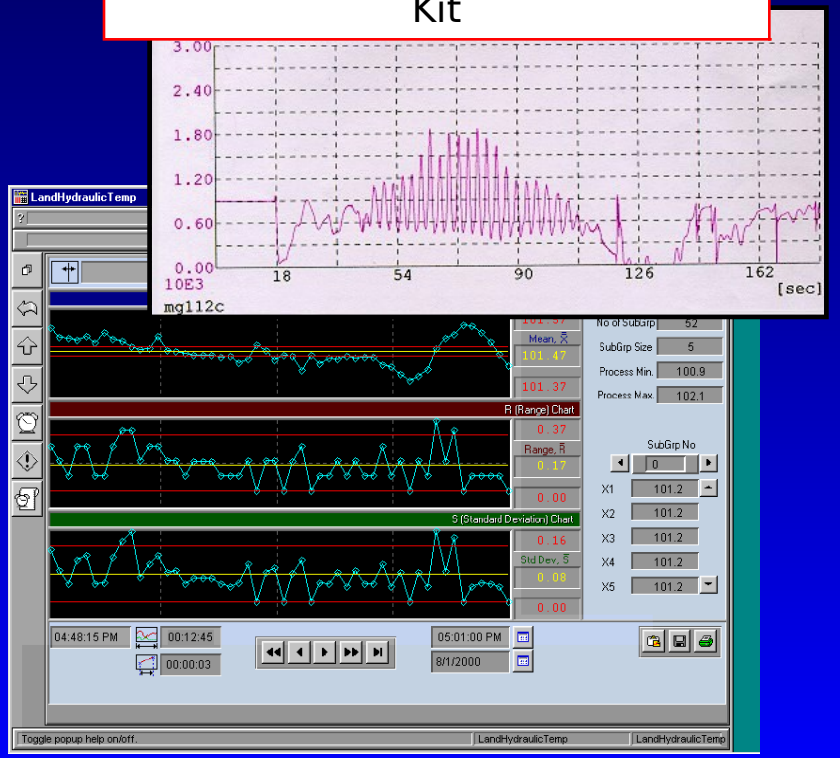


- All events are logged on an event-basis including time stamp
- The data is organized graphical and tabular (EXCEL spreadsheet) format
- The graphs show real-time data vs. time and recorded on an event-based trigger

Predictive Maintenance

- **Involves condition monitoring of equipment, and a methodology for the performance of maintenance only when there is objective evidence of need**
- **Part of an overall maintenance effort**
  - **to prevent unscheduled downtime from failure**
  - **predict the opportune time for maintenance.**
- **Currently, periodic inspections are conducted to allow for detailed observations of equipment and critical structural steel components of gates.**

Hand-held Vibration Monitoring Kit



Summary

1. A PLC control system can be used for high-speed collection of the data from instrumentation transducers used to monitor the condition of lock equipment.

2. Data trending and analysis has potential for future long-term prediction of maintenance based on the changes to operating machinery conditions.

3. More research is needed to determine how best to use condition monitoring data to predict maintenance, and how to automate the process to produce the most cost-effective results.

4. Results of this research should be incorporated in Corps of Engineers guidance, Engineer Manual (EM)-1110-2-2610, “Gate Operating Equipment for Navigation Locks and Spillways.”

5. Future cost savings might be attainable if system is applied on a global scale.

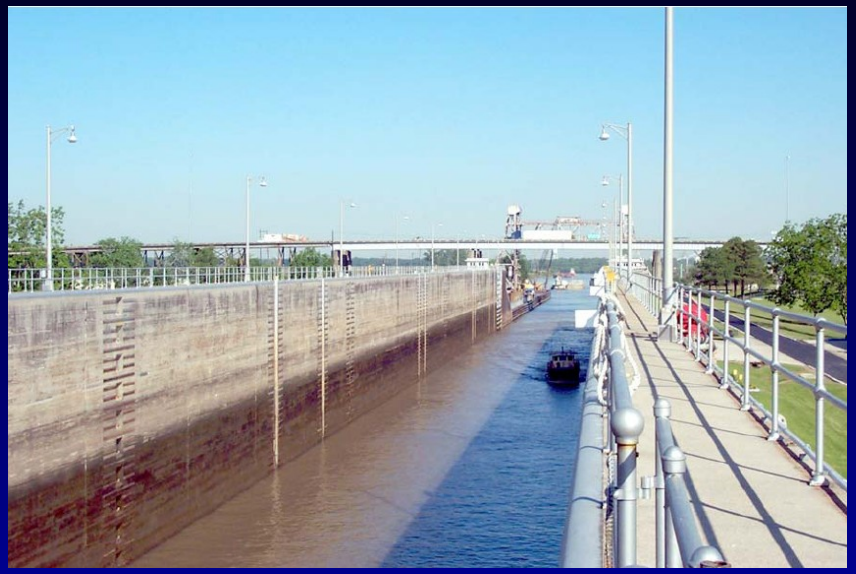
BACKUP SLIDES

Problem

- The U.S. Army Corps of Engineers operates 278 locks in the United States
- Lock operating machinery must be properly maintained to prevent lock closures or reduced efficiency.
- Unscheduled machinery maintenance can be very costly
- and disruptive.
- Lock and dam components are subject to failures
  - excessive wear of components from routine use or from excessive loading, as may occur when large debris obstructs the proper movement of the gate.
- The excessive loads and wear may eventually result in irreparable damage to the machinery.
- Also, critical components used in gates are subject to fatigue and wear.
  - In some cases, fatigue of these components can lead to eventual loss of a gate if the problem is not corrected.

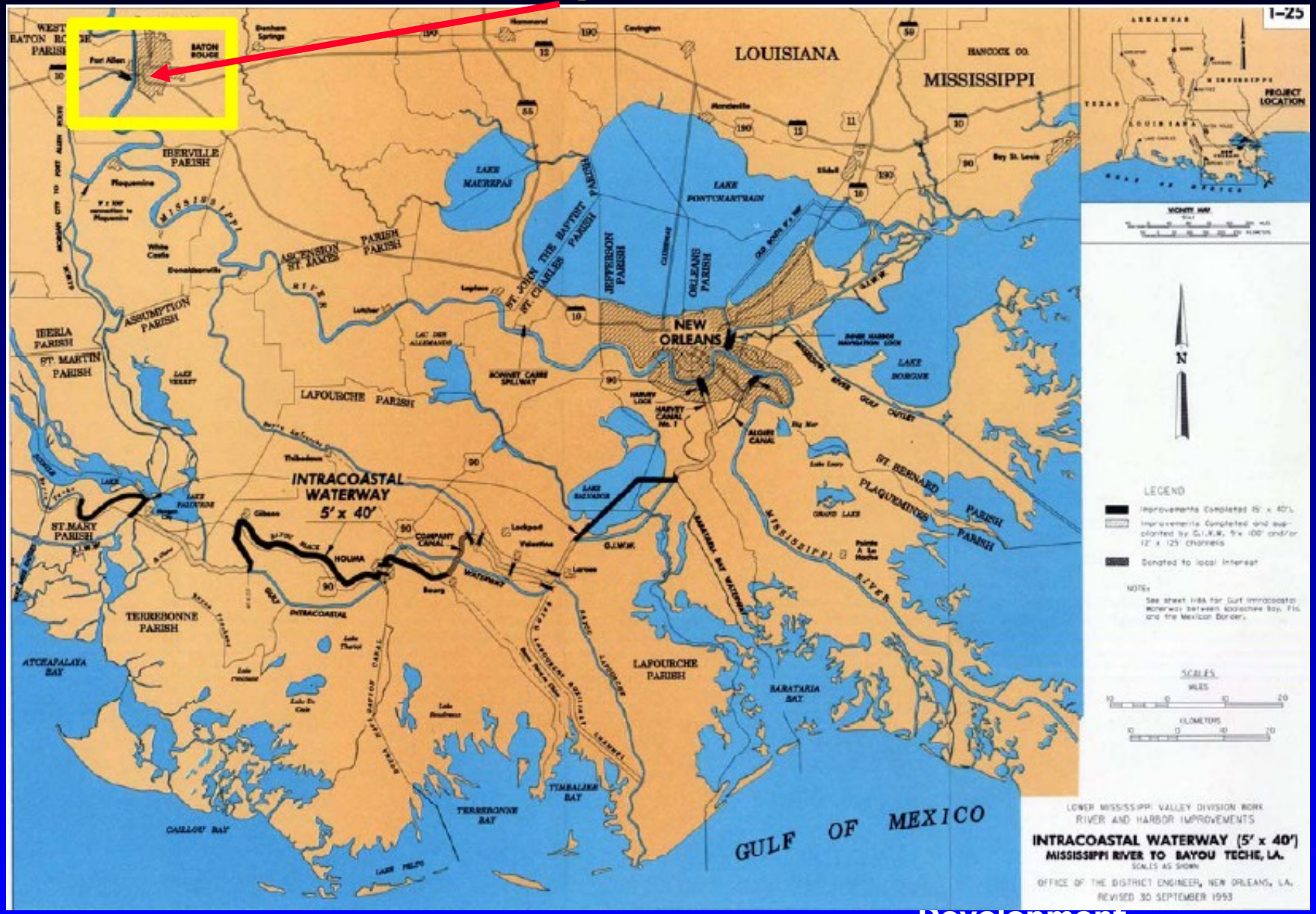
Port Allen Lock

- Port Allen Lock is on the Gulf Intracoastal Waterway (GIWW) between Morgan City, TX, and Port Allen, LA,
- Approximately 1/10 mile from the Mississippi River Entrance to the Canal at Baton Rouge, LA
- The lock is 84 ft wide by 1,200 ft long
- Maximum lift of 32 ft at river stage 40.0.
- miter gates and reverse tainter valves at both ends of the lock around 8,000 lockages annually.



Port Allen Lock is considered critical to navigation interests on the GIWW and to flood control interests.

Location of Port Allen on the GIWW



Installation of PLCs

The PLC system Modicon's Quantum Q534-14

A built-in web server is part of the processor I/O rack Ethernet interface card.

The web server is limited in space and has limited graphical applications (when compared to the HMI software Intellution iFix), but it has the ability to allow certain read-only data to be displayed using nothing more than Microsoft®'s standard Internet Explorer (IE) package. This option allows anyone within the Corps of Engineers firewall protection to see the data.

Port Allen PLC/Condition Monitoring Upgrade

- **RS View32 RAD client software/HMI/GUI Display Screens:**
  - **indicate gate positions, water levels, weather information, and gate operating mode.**
  - **provides operating controls for all specified Lock functions.**

- **Existing motor controllers and starters will be modified as necessary to operate with new control schemes.**

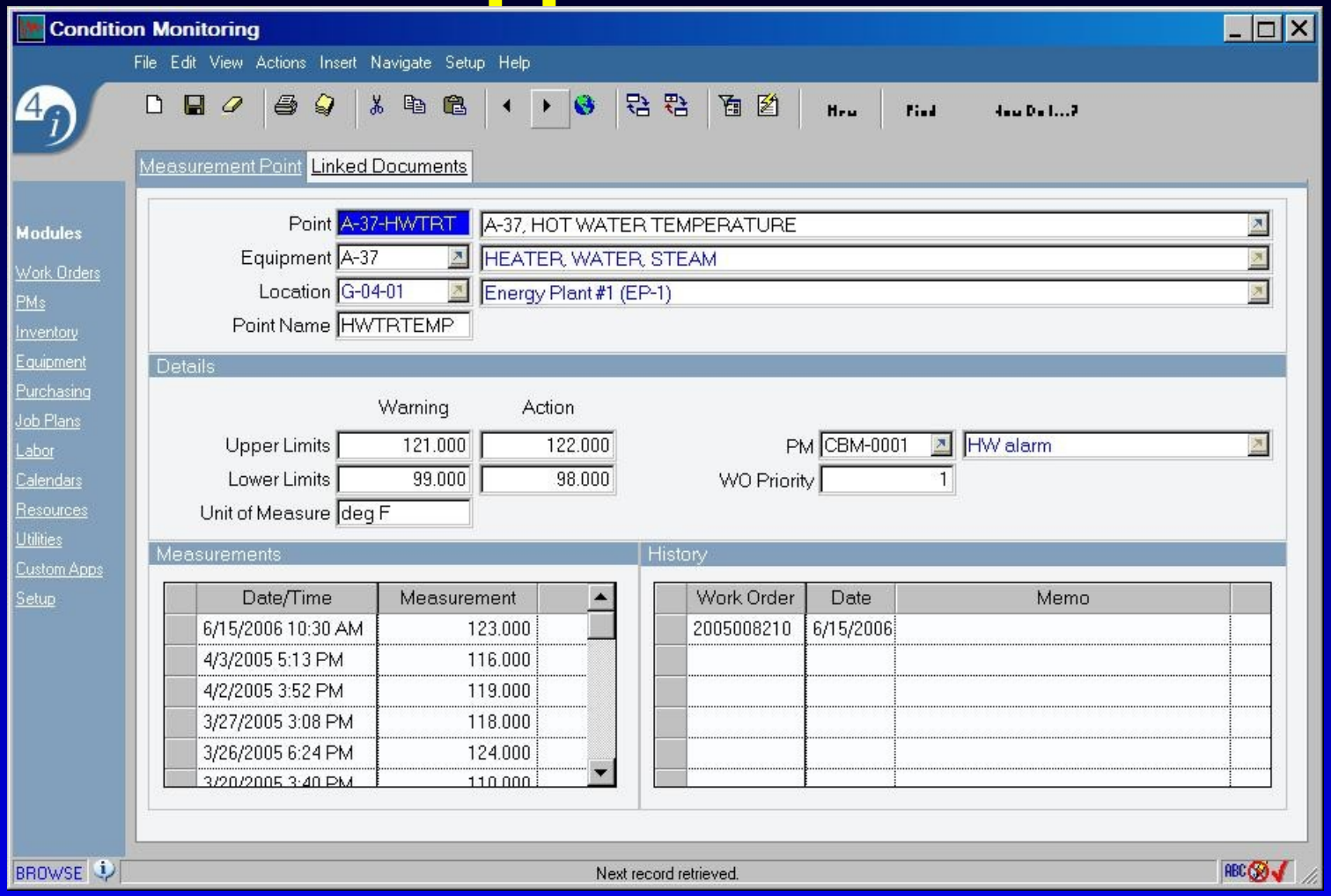
- **Solid state relays in each gate and valve controller will monitor incoming power (loss of power, loss of phase, phase reversal) and provide indication (contact closures) when abnormal conditions arise.**

- **Control sequences will have inherent error checking and "self diagnostics".**
  - **If the expected result of a user input is not achieved in a defined period of time, the HMI shall provide a descriptive message on the screen indicating where the problem exists.**

Maximo

- Work scheduling, execution, and time/cost tracking tool
- Retain corporate knowledge of past actions
- Client-server and web versions
- Highly customizable
- Modules
  - Equipment, Inventory, Job Plans, PM, Work Orders, Purchasing, Resources

Condition Monitoring Application

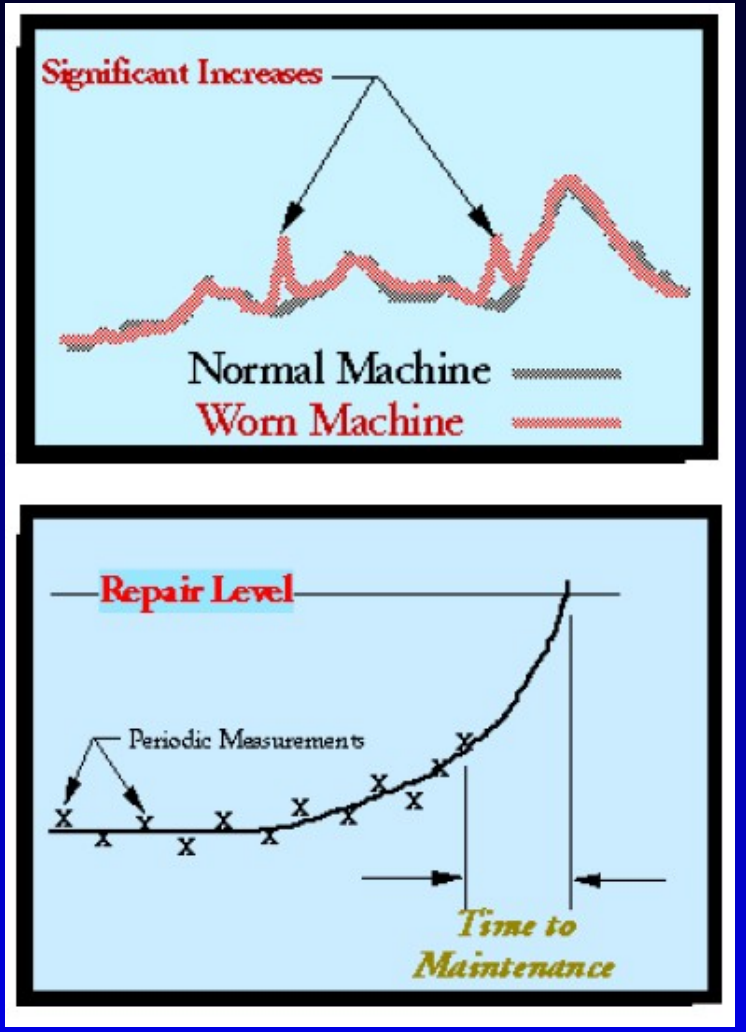


Condition Monitoring Scenarios

- **Limit exceeded**
  - **Signal with audible alarm from HMI software**
  - **Generate approved work order in FEM to capture accomplished work details**
- **Trend indicating impending failure**
  - **Generate un-approved work order in FEM for supervisor approval and scheduling**

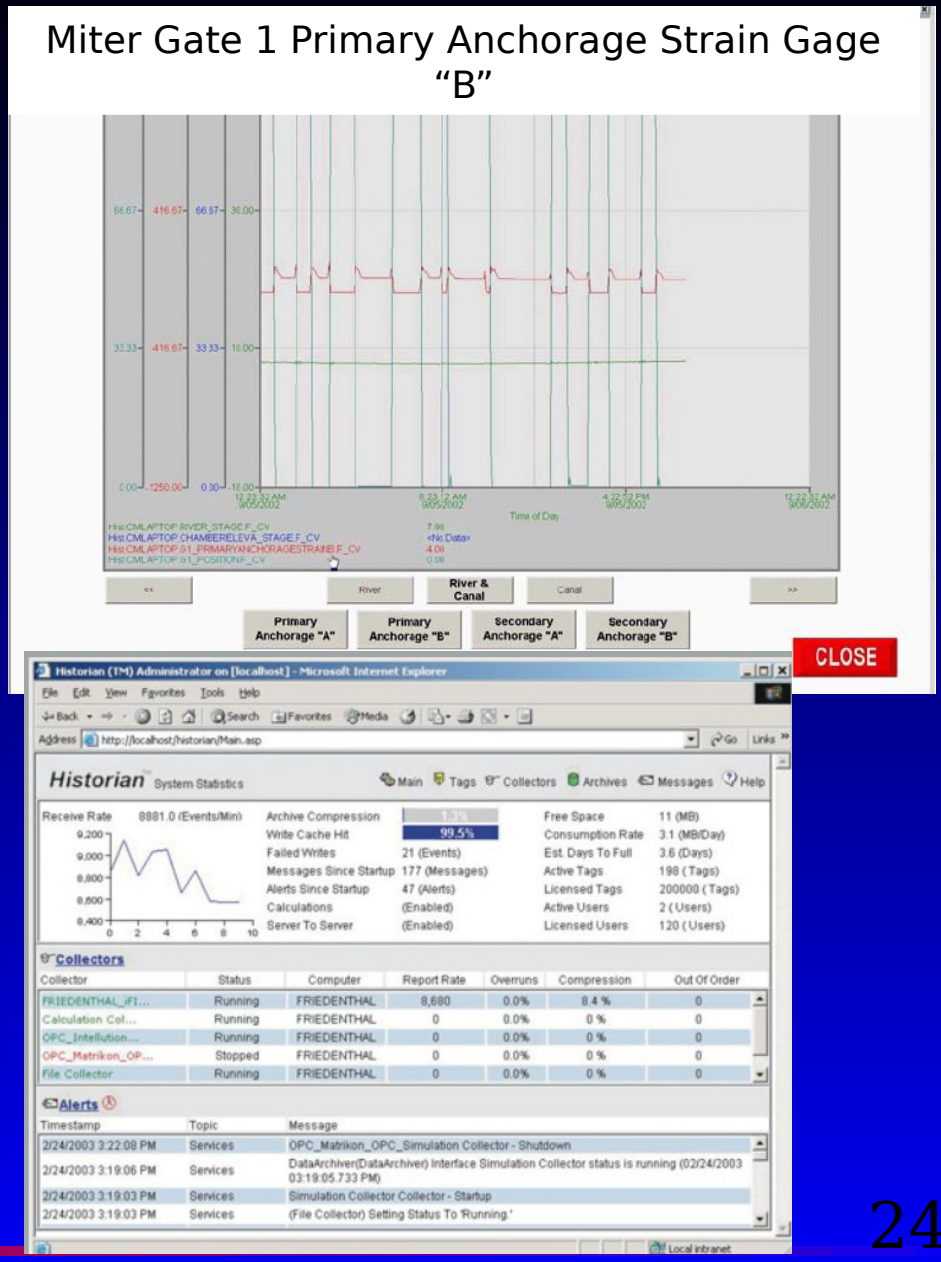
Vibration Signature Curve

- Develop an operating “signature curve” benchmark of the vibration spectrum.
- Through long-term trending and data comparison of the vibration spectrum, patterns of wear and degradation can be determined long before catastrophic failure.
- Using special signal processing techniques and statistical analyses, monitor the progress of any machine faults causing increasing vibration.
- Decide how much maximum vibration to allow
- Amount of vibration caused by a particular fault can be trended
- Prediction can be made for how much time is left before the repair should be done



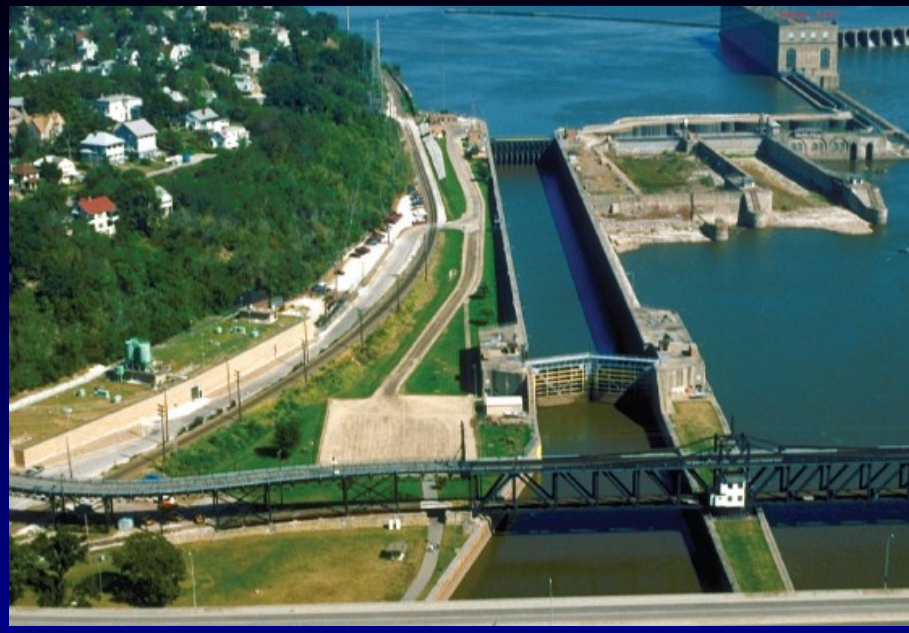
Data Trending

- **HMI package, RSView TrendX**
- **Records the data values on a predetermined time basis and store this information for analysis.**
- **Relational databases, will automatically analyze the data collected by RSView TrendX for specific trends.**
- **All data are date and time stamped and can be stored in an Excel spreadsheet for analysis.**



Research and Development

- The installed sensors include:
  - Hydraulic Cylinder **Position**
  - **Pressure**, Hydraulic Oil, Pool, Tail, & Lock water levels
  - Hydraulic Oil **Flow** rate
  - **Temperature** (Oil & Ambient)
  - Magnetic **Proximity** Switches
  - Manual (lockman) inputs
- All inputs are logged on an event- basis including time-stamp.



- The data is organized in both graphical and tabular (*Excel spreadsheet*) format for maintenance & trouble shooting
- The graphs show real-time data, vs time, and recorded on an event-based trigger.